Estimation of Spatial Variation in Vegetation of Fragmented Forests in Kahuta

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Abstract

This study examines spatial variations in vegetation within a fragmented forest ecosystem, investigating the impact of forest fragmentation on biodiversity and ecological processes at Kahuta forest. A stratified random sampling technique was employed, with data collected on vegetation parameters in five elevation zones. Transects were used, each with five 10 x 10 meter sample plots, totalling 25 plots. Elevation, slope, aspect, and coordinates were recorded, and species identified. Parameters studied included frequency, cover, density, and IVI as statistical index, and ANOVA applied. The study gives crucial information on plant communities in various zones and elevations. Pinus roxburghii is the dominant species throughout all zones, with the highest IVI. In zone III, Olea ferruginea plays a significant role. Acacia modesta, Cassia fistula, and Morus alba all make significant contributions. Shrubs that contribute to biodiversity include Dodonea viscosa, Carica opaca, and Agave sisalana. To compare ecological parameters from zone I to zone V along an altitudinal gradient to compare the mean scores of different species within each zone. The findings indicated significant differences in group means, with p-values significantly lower than the conventional 0.05 significance level, indicating that the observed variances were statistically significant. These findings highlight the ecological significance of altitude and species interactions in shaping plant communities within the examined region.

Keywords: Kahuta Forest, Spatial Variation, Fragmented Forest.

Introduction

The decline of natural habitats is a key driver of global biodiversity loss. Habitat degradation typically results in fragmentation, which involves the division of habitat into smaller and more isolated parts, separated by a matrix of human-modified land cover. (Haddad et al., 2015). The reduction in area, increased isolation, and increased vulnerability to human land activities along fragment margins cause long-term changes in the structure and function of the surviving fragments (Young and Boyle, 2000). Human-caused forest fragmentation is becoming a growing issue. These forests are crucial for biodiversity and climate regulation, but they are

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currently at risk of degradation. This fragmentation is creating imbalances in plant cover and affecting the ecosystem. To conserve our forests, we urgently need to understand the scope and effects of this problem (Carleton & Maycock, 1980). Large-scale forest clearing can result in habitat loss and biodiversity decline, while intensive farming practices can lead to soil degradation and reduced plant diversity. Spatial variation in vegetation has important ecological and economic implications. (Gao et al., 2017). Forest fragmentation is a common phenomenon that causes several ecological changes, contributing to biodiversity decline. This fragmentation is caused by factors such as industrialisation, urbanisation, erosion, road construction, and forest fires (Zhang et al., 2021).

Fragmentation affects natural ecosystems, causing forests to become smaller, the forest edge to expand, and surviving forest patches to become increasingly isolated. Natural events and human actions contribute to forest fragmentation. (Gonzalez et al., 2011). According to WCMC estimates, Pakistan's total forest cover is only 3.7%, and this vital natural resource is under danger from catastrophic deforestation. Pakistan is a country with limited forest coverage. 5.36% of the total area, or 4.72 million ha, is covered by forests. This differs significantly from several other countries in the world, namely Bangladesh (15.3%), Malaysia (65.5%), Sri Lanka (42.4%), India, and China (17.7%), all of which use progressive forestry techniques. The world average per capita woodland size is one hectare. The majority of Pakistan's land, approximately 70–80%, is located in dry or semi-arid regions with insufficient precipitation to support tree growth, which is the primary reason for the area's small size compared to the minimal forest area of 0.033 hectares (Bhatti, 2011).

Kahuta cover a small portion of Pakistan, about 2.2% of the country's territory, but plays an essential part in ecosystem services. However, they are at risk from deforestation (NFRC). The majority of Pakistan's land, 70–80%, is located in dry or semi-arid regions, which is the main reason that makes them vulnerable (Bhatti, 2011). In Kahuta, climate varies from tropical to sub-tropical. During the rainy season, rainfall is highest (Sajjad et al., 2021; Wang et al., 2021). Vegetation is the key component of an ecosystem. Spatial variation in vegetation refers to the differences in plant communities that occur across different locations and landscapes. A range of factors, including climate, topography, soil type, and human activities, can influence this variation. Topography can also play a role, with plant communities depending on the slope, aspect, and elevation of a particular area (Zhang et al., 2021). Forests are vital for biodiversity and play a crucial role in regulating climate change; however, they are under threat worldwide due to anthropogenic activities, such as those in Kahuta, Pakistan. Fragmentation creates significant variation in plant cover, which has ecological consequences. Estimating this variation is crucial for understanding the impact of fragmentation on the ecosystem (Carleton & Maycock, 1980). Human activities, such as deforestation, urbanisation, and agriculture, can also cause significant changes in the vegetation patterns of the study area. For instance, the clearing of forests can result in the loss of habitat and biodiversity. Additionally, farming practices can cause soil degradation and reduced plant diversity. (Gao et al., 2017).

Fragmentation alters the vegetation dynamics in subtropical forests of the study area, and due to forest fragmentation, it creates more severe impacts on the variation in floral diversity, leading to population declines.

This research has the following objectives:

1. Access the causes of fragmentation and variation of floral diversity in the fragmented forest of Kahuta.
2. Examine the influence of topography on vegetation dynamics of Kahuta Forest.

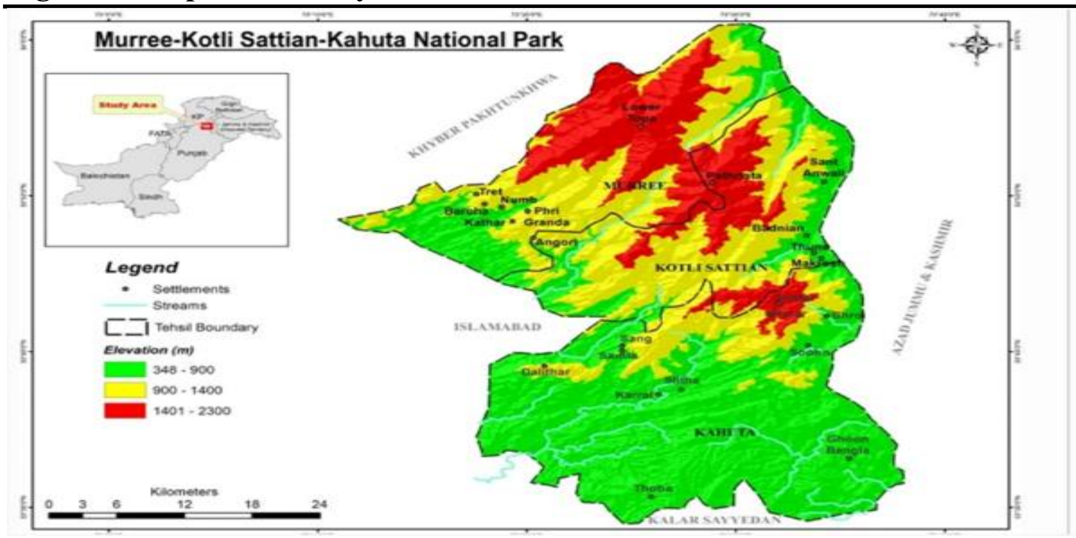
Our study in this forest aims to identify the impacts of forest fragmentation on biodiversity and ecosystems, as well as its effects on floral diversity variation. In a world where trees are disappearing, our research in Kahuta may provide crucial insights for forest conservation.

Materials and Methods

Study Area

Kahuta forest is situated in Rawalpindi district in Pakistan, located between latitudes 33° 34'60.00 "N and longitude 73° 22'60.00 "E in the foothills of the Potohar mountain range. The climate of this region is classified as subtropical continental, with hot summers and cool winters. The summer season in Kahuta Forest typically begins in May and lasts through September, with average high temperatures ranging from 32 °C to 38°C (90°F to 100°F) and low temperatures averaging around 22 °C to 25°C (72°F to 77°F). The winter season in Kahuta Forest usually lasts from November through February, with average high temperatures ranging from 16 to 21°C (61 to 70°F) and low temperatures averaging around 5 to 9°C (41 to 48°F). On average, 1,249 millimetres of rainfall fall every year, with the majority of it occurring during the rainy season (Qureshi & Shaheen, 2013).

Figure 1: Map of the study area



In comparison to the lower elevation, the topography at higher altitudes is made up of rough terrain with small valleys. At higher altitudes, topography is generally composed of rocky terrain with small valleys, whereas it is mostly flat at lower altitudes (Sajjad et al., 2021). Kahuta contains Coniferous forest that cover an area of total 80129 acres. Chir, Kahu, and Phulai are the primary species in the area. Fragmentation can result from natural phenomena such wildfires, erosion, flooding, and volcanic eruptions. Logging is a major cause of habitat fragmentation in Kahuta forests. Road construction and illegal cuttings are also causes fragmentation. Fragmentation creates bad impacts on vegetation diversity and that cause the population decline in the study site (forest department).

Figure 2: The forest fragmentation in the study area

Study Design

Stratified random sampling was carried out. Sampling sites were selected at various elevation zones and quantitative data of vegetation like density, frequency, cover and IVI were recorded from different blocks at different elevation zones to access the vegetation data. For data collection transect method was utilized, and sample plots were randomly placed. Each sample plot had a size of 10x10 meters. The study area was divided into 5 elevation classes with a difference of 200 meters between each class. At each elevation, a transect was laid out and five sample plots were taken from the forest overstory and understory. The length within the plots was 100 meters, and every plot had a size of 100 m². Total, 25 plots were laid out in the study area. GPS, slope, aspect, elevation, and geographic coordinates were recorded using a Clinometer, Compass, and Navigation system. The species were identified by their common names with the help of local experts and then converted into binomial nomenclature using Pakistani flora and systems biology guidelines by Nasir and Ali (1972).

Following formulas have been used for the calculation of, species density, frequency, coverage and IVI.

Species density: The no of trees per unit area. Density can be calculated on the basis of per acre/hectare/meter. In the present study density was calculated on the basis of per hectare. For the calculation of density, the following formula was used (Hussain, 1989)

$$\textit{Species density} = \frac{\text{No, of species in all sample plots}}{\text{Total area sample}}$$

Species Frequency: The occurrence of specie in the particular plot. Frequency is measured in percentage (Hussain, 1989).

$$\text{Frequency} = \frac{\text{No, of sample plots in which individual species was present}}{\text{Total number of sample plots taken}} \times 100$$

Species Cover: Vertical projection of the crown on the, ground. The unit of crown cover is ft² or m². In present study the cover was measured in square meter by using the formula. Bhat et al. (2020).

$$\text{Species cover} = \frac{\text{Area cover of a species in all sample plots}}{\text{Total area covers by the all specie in all sample plots}} \times 100$$

$$\text{Relative Frequency} = \frac{\text{Species frequency across all sample plot}}{\text{All species frequency in all sample plots}} \times 100$$ (Hussain, 1989).

$$\text{Relative Density} = \frac{\text{Density of a species in across all sample plots}}{\text{Total species density in all sample plots}} \times 100$$

Relative Coverage = Species in whole sample plots x 100

Cover of each species in overall sample plots Bhat et al. (2020).
Important Value = RD+RF+RC
Where
RD= relative density, RF= relative frequency, RC= relative cover (Tegegne &Workineh, 2017).

Importance Value Index
The sum of all the values of RD, RF, RC and dividing it by four (Tegegne &Workineh, 2017).

$$IVI = \frac{\text{IV of a species}}{4}$$

To examine the means, LSD method, was applied for the examine of vegetation parameters. Plant abundance and species richness were determined based on the elevation gradient using the Transect method. The data obtained were analyzed using statistical methods such as ANOVA for test the treatment effects and determine the significance of the results. The Software Excel was used for all statistical analysis.
Table 1 shows five elevation zones, elevation ranges, no of sample plots and sampling area of per plots.

Table 1: Elevation zones

S. No	Zones	Elevations ranges	No of sample plots	Sampling area per plot
1		500-870 meters	5	100-meter square
2		870-1150 meters	5	100-meter square
3		1150-1380 meters	5	100-meter square
4		1380-1600 meters	5	100-meter square
5		1600-1750 meters	5	100-meter square
			Total 25	

Results

Floristic Composition

Results revealed that total 12 species and nine families were identified in the research region, of which 5 tree species, 5 shrubs and 2 grasses have been identified. The variation in various areas of environmental zones demonstrated variation in vegetation in terms of diversity of species and composition of the study area. The main tree species of the study area *Pinus roxburghii, Acacia modesta, Olea ferruginea.* Shrubs species found in the study were *Adhatoda vasica, Carissa opaca, Jasminum mesnyi, Agave sisalana* and *Dodonea viscosa.* The species were categorized on the basis of their frequency and percentage. The study showcase that the dominant species is *Pinus roxburghii* that found in most zones and second is *Acacia modesta* which is found in most classes and the third species is *Olea ferruginea* which is also found in most classes. *Dodonea viscosa, Carissa opaca, Agave sisalana and Jasminum mesnyi* are frequently present in the area.

Table 2: Floristic Composition of the research region

Sr. No	Botanical Names	Family	Local Name	Type
1	*Pinus roxburghii*	Pinaceae	Chir	Tree
2	*Acacia modesta*	Fabaceae	Phulai	Tree
3	*Morus alba*	Moraceae	Mulberry	Tree
4	*Olea ferruginea*	Oleaceae	Kahu	Tree
5	*Cassia fistula*	Fabaceae	Amaltas	Tree
6	*Dodonea viscosa*	Sapindaceae	Snatha	Shrub
7	*Adhatoda vasica*	Acanthaceae	Vasaka	Shrub
8	*Carissa opaca*	Apocynaceae	Garanda	Shrub
9	*Jasminum mesnyi*	Oleaceae	Jasmine	Shrub
10	*Agave sisalana*	Asparagaceae	Sisal	Shrub
11	*Cynodon dactylon*	Poaceae	Kabal	Grass
12	*Cenchrus ciliaris*	Poaceae	Dhaman	Grass

Community Dominance of Zone I (500 To 870 M)

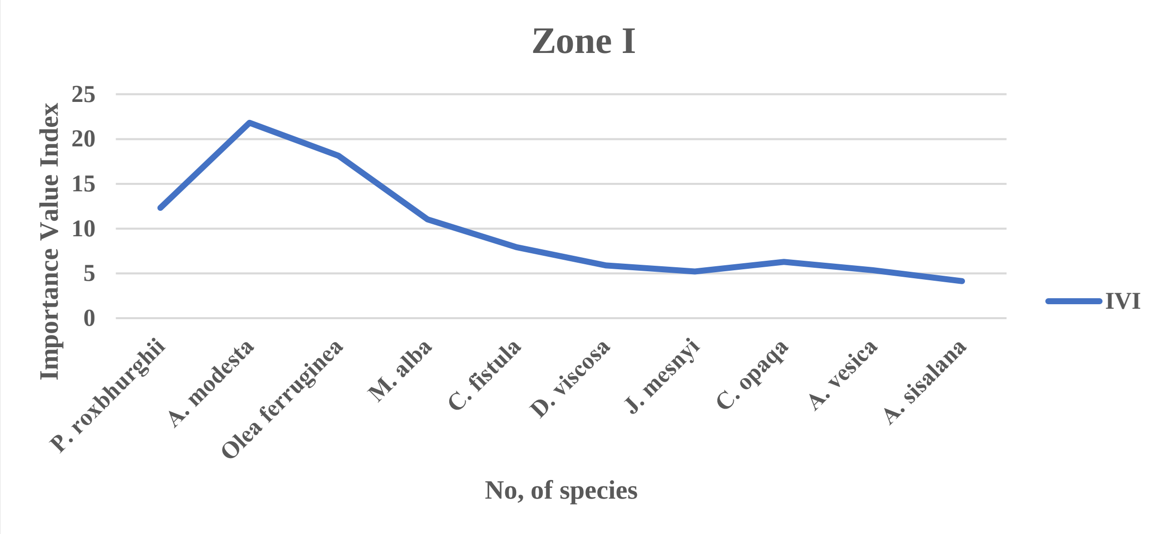
In Zone I, the major tree vegetation comprises several notable species, including *Pinus roxburghii, Olea ferruginea, Acacia modesta, Morus alba* and *Cassia fistula* were observed. Additionally, the area is adorned with a variety of shrubs, example *Dodonea viscosa, Jasminum mesnyi, Carica opaca, Adhatoda vasica,* and *Agave sisalana.* While using the statistical index density ha^{-1}, Frequency (%), Cover m^2 ha^{-1}, Relative Density (RD %), Relative frequency (RF %), Relative Cover (RC %), IV IVI were analyzed (Table 3). *Acacia modesta* stands out with the highest Importance Value Index (IVI) of 21.8, indicating its significant importance within the community. Following closely, *Olea ferruginea* IVI (18.1), *Pinus roxburghii* IVI (12.3), *Morus alba* IVI (11.0), and *Cassia fistula* with an IVI value of 7.9 respectively. Shrubs vegetation, *Carica opaca* has the maximum IVI of 6.2. Following closely, *Agave sisalana* (4.1) IVI, *Dodonea viscosa* IVI (5.8), *Adhatoda vasica* (5.3) IVI and *Jasminum mesnyi* with and IVI value of 5.1 respectively.

Table 3: Phytosociological attributes of species in Zone I (500–870 m asl)

Species	D	F	C	R.D	R.F	R.C	IV	IVI
P. roxburghii	50	40	40	14.9	6.45	15.5	36.9	12.3
A. modesta	100	100	50	29.8	16.1	19.4	65.4	21.8
O.ferruginea	50	100	60	14.9	16.1	23.3	54.4	18.1
M. alba	23	90	30	6.8	14.5	11.6	33.0	11.0
C. fistula	20	50	25	5.97	8.06	9.72	23.7	7.9
D. viscosa	19	50	10	5.67	8.06	3.89	17.6	5.8
J. mesnyi	15	40	12	4.47	6.45	4.66	15.5	5.1
C. opaca	19	60	9	5.67	9.67	3.50	18.8	6.2
A. vasica	19	40	10	5.67	6.45	3.89	16.0	5.3
A. sisalana	20	50	11	0.05	8.06	4.28	12.4	4.1

D; density ha^{-1}, F; Frequency (%), C; Cover m^2 ha^{-1}, R.D, RF, RC, IV and IVI.

Figure 3: The Importance Value Index in zone I.



Community Dominance of Zone II (870 To 1150 M)

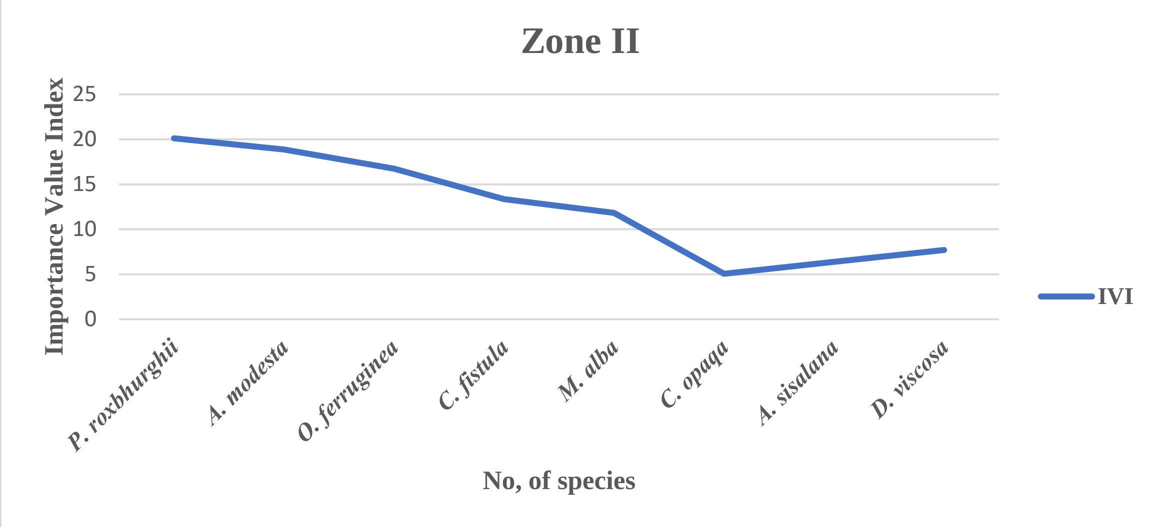
In Zone II, the major tree vegetation comprises several species, including *Pinus roxburghii, Olea ferruginea, Acacia modesta, Morus alba* and *Cassia fistula*. Additionally, the area contains variety of shrubs, like *Dodonea viscosa, Jasminum mesnyi, Carica opaca, Adhatoda vasica,* and *Agave sisalana.* Among these plant species, *Acacia modesta* stands out with the highest IVI of 18.8, indicating its significant importance within the community. Following closely, *Olea ferruginea* secures the second position with an IVI value of 16.7, highlighting its considerable ecological significance. *Pinus roxburghii* claims the third spot with an IVI value of 20.1, signifying its vital role in the plant community. *Cassia fistula* secures the fourth position with an IVI value of 13.3, contributing to the area's vegetation and *Morus alba* with an IVI value of 11.8. Among the shrubs vegetation, *Dodonea viscosa* has the maximum IVI value of 7.6 and *Agave sisalana* is the second with 6.36 and is the third *carica opaca* with 5.04 respectively. The vegetation community in this region primarily consists of, *Acacia modesta, Olea ferruginea, Pinus roxburghii, cassia fistula, Morus alba* and *shrub* like *Dodonea viscosa, Carica opaca* and *Agave sisalana* respectively.

Table 4: Phytosociological attributes of species in Zone II ((870-1150 m asl)

Species	D	F	C	R.D	R.F	R.C	IV	IVI
P. roxburghii	90	90	60	18.7	20	21.5	60.3	20.1
A. modesta	100	80	50	20.8	17.7	17.9	56.5	18.8
O. ferruginea	80	70	50	16.6	15.5	17.9	50.20	16.7
C. fistula	70	50	40	14.5	11.1	14.3	40.08	13.3
M. alba	50	40	45	10.4	8.8	16.1	35.49	11.8
C. opaca	20	30	12	4.16	6.6	4.31	15.14	5.04
A. sisalana	30	40	11	6.25	8.8	3.95	19.09	6.36
D. viscosa	40	50	10	8.33	11.1	3.59	23.04	7.68

D; density ha-1, F; Frequency (%), C; Cover m2 ha-1, R.D, RF, RC, IV and IVI.

Figure 4: The Importance Value Index in zone II



Community Dominance in Zone III (1150 to 1380 M)

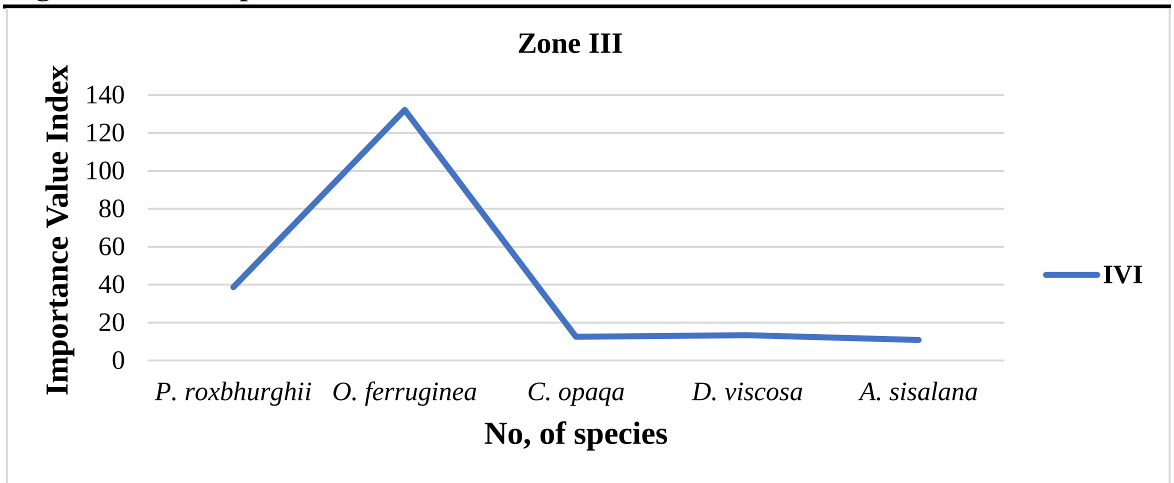
In Zone III, the major tree vegetation is characterized by two prominent species: *Pinus roxburghii* and *Olea ferruginea*. The zone is adorned with three notable shrub species: *Dodonea viscosa, Carica opaca,* and *Adhatoda vasica.* Among these plant species, *Olea ferruginea* stands out with the maximum IVI of 132.1, indicating its significant importance within the community. *Pinus roxburghii* secures the next position with an IVI value of 38.6. Among the shrubs vegetation, *Dodonea viscosa* has the highest IVI value of 13.41 and *Carica opaca* is the second with IVI value of 12.2 and is the third *Agave sisalana* with the value of 10.83. Vegetation community in this region primarily consists of *Olea ferruginea, Pinus roxburghii,* and shrub like *Dodonea viscosa, Carica opaca* and *Agave sisalana*.

Table 5: Phytosociological attributes of species in Zone III (1150 -1380 m asl)

Species	D	F	C	R.D	R.F	R.C	IV	IVI
P.roxburghii	120	100	70	37.5	33.3	45.1	115.9	38.6
O.ferruginea	80	50	50	25	16.6	354.8	396.5	132.1
C. opaca	50	40	13	15.6	13.3	8.3	37.3	12.4
D. viscosa	40	60	12	12.5	20	7.74	40.24	13.41
A. sisalana	30	50	10	9.37	16.6	6.45	32.49	10.83

D; density ha^{-1}, F; Frequency (%), C; Cover m^2 ha^{-1}, R.D, RF, RC, IV, and IVI.

Figure 5: The Importance Value Index in zone III



Community Dominance of Zone IV (1380 To 1600 M)

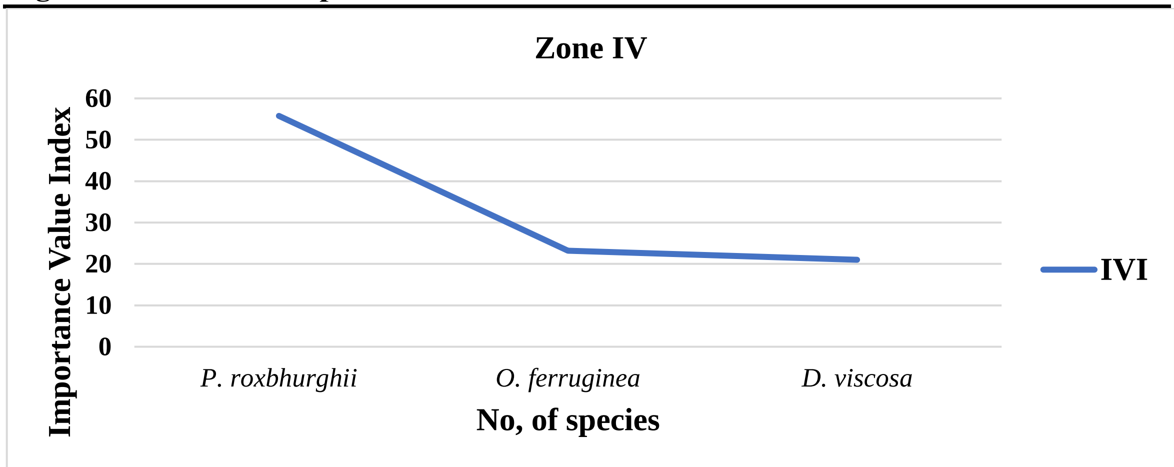
In Zone IV, the major tree vegetation is characterized by two prominent species: *Pinus roxburghii* and *Olea ferruginea*. In addition to the trees, the zone is containing one shrub specie that is *Dodonea viscosa*. Among these two plant species, *Pinus roxburghii* stands out with the highest IVI of 55.7, indicating its significant importance within the community. Following closely, *Olea ferruginea* secures the second position with an IVI value of 23.2. Among the shrubs vegetation, only *Dodonea viscosa* has the highest IVI value of 21.0.

Table 6: Phytosociological attributes of species in Zone IV (1380-1600 m asl)

Species	D	F	C	R.D	R.F	R.C	IV	IVI
P. roxburghii	130	100	90	59.0	43.4	64.74	167.3	55.7
O. ferruginea	50	50	35	22.7	21.7	25.17	69.64	23.2
D. viscosa	40	80	14	18.1	34.7	10.07	63.03	21.0

D; density ha^{-1}, F; Frequency (%), C; Cover m^2 ha^{-1}, R.D, RF, RC, IV and IVI.

Figure 6: shows the Importance Value Index in zone IV



Community Dominance in Zone V (1600 To 1750 M)

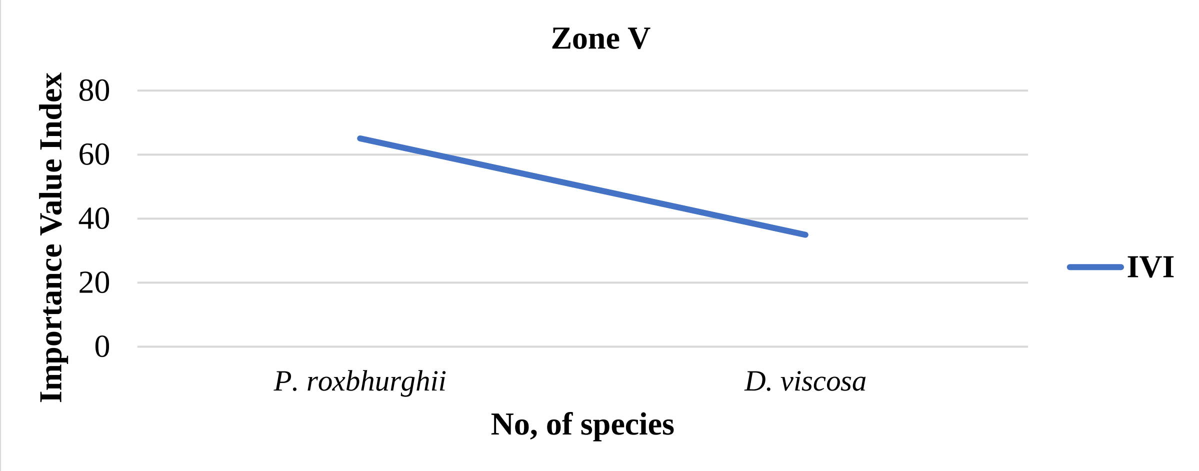
In Zone V, the major tree vegetation is characterized by one prominent specie that is pure *Pinus roxburghii* and in addition to the tree specie, the zone is containing one shrub specie that is *Dodonea viscosa*. In this zone only pure *Pinus roxburghii* stands out with the IVI of 65.0, indicating its significant importance. Among the shrubs vegetation, only *Dodonea viscosa* has the highest IVI value of 34.9.

Table 7: Phytosociological attributes of species in Zone V (1600-1750 m asl)

Species	D	F	C	R.D	R.F	RC	IV	IVI
P. roxburghii	150	100	100	68.1	55.5	71.4	195.1	65.0
D. viscosa	70	80	40	31.8	44.4	28.5	104.8	34.9

D; density ha^{-1}, F; Frequency (%), C; Cover m^2 ha^{-1}, R.D, RF, RC, IV and IVI.

Figure 7: Importance Value Index in Zone V



Single Anova factor along the Altitudinal gradient from 500-1750 meters asl

Table 8: One-way ANOVA of densities from zone I to zone V

Names	df	F	Mean	Std. Dev.	N	*p*-value
Zone I	4	3.327282	31.66	25.3	285	0.0191
Zone II	40		43.33	34.2	390	
Zone III			22.22	39.4	200	
Zone IV			4.44	39.5	40	
Zone V			7.77	47.4	70	

A one-way ANOVA was performed on the density data across an elevation range of 500 to 1750 meters, from zone I to zone V, to assess the differences in mean scores between different species. The ANOVA test resulted in an F-value of (4, 40). The ANOVA table revealed that there is a significant difference among the average of the groups (P-value = 0.019179004). Since the P-value (0.019179004) is less than the significance level typically chosen (e.g., 0.05), we reject the null hypothesis, which assumes that there are no significant differences among the group mean. The F-ratio is 3.327282319, which indicates that the variation between groups means is approximately 3.33 times larger than the variation within groups. The critical F-value (F crit) at a certain significance level (alpha) is 2.6059749. ANOVA results for the variable DENSITY show that there is a significant difference among the group means (p-value = 0.019). The F-ratio (3.327) is greater than the critical F-value at the 0.05 significance level, indicating that the differences between the means of the groups are statistically significant. Hence, there are significant differences in the densities among the five zones, as indicated by the ANOVA results.

Table 9: One-way ANOVA of frequencies from zone I to zone V

Names	df	F	Mean	Std. Dev.	N	*P*-value
Zone I	4	6.209495	64.44	23.57	580	0.00052
Zone II	40		40	28.72	360	
Zone III			22.22	33.46	200	
Zone IV			14.44	36.89	130	
Zone V			8.888	36.27	80	

To analyse the changes in mean scores between various species in different zones, a one-way ANOVA was performed on the altitudinal gradient data from zone I to zone V frequencies. The F-value for the ANOVA test was (4, 40). According to the ANOVA table, there is a significant difference between the group averages, as demonstrated by the low p-value (0.000552339), which is less than the normal significance criterion of 0.05 (5%). As a result, we may reject the null hypothesis of no difference in group means. ANOVA findings for the variable FRQUENCY show a highly significant difference among the group means (p-value < 0.001). The F-ratio (6.209) is greater than the critical F-value (2.606) at the 0.05 significance level, which reveal that the variation within the means of the groups are statistically significant.

Table 10: One-way ANOVA of Cover from zone I to zone V

Names	df	F	Mean	Std. Dev.	N	*p*-value
Zone I	4	3.061487	24.1111	17.79	217	0.027
Zone II	40		23.6666	21.70	213	
Zone III			9.44444	23.26	85	
Zone IV			5.44444	27.54	49	
Zone V			4.44444	31.04	40	

A one-way ANOVA was performed on the altitudinal gradient data across zone I to zone V cover to assess the differences in mean scores between different species within each zone. The ANOVA results reveal a significant difference in group averages (p-value = 0.027). The F-ratio (3.061) is more than the necessary F-value (2.606) at the 0.05 significance level, indicating that the differences in group means are unlikely to be due to chance. As a consequence, there is evidence that the variable COVER influences the outcome in a statistically significant manner. The ANOVA results for the variable COVER show that the averages of the groups differ considerably. The F-ratio is greater than the critical F-value at the 0.05 significance level, indicating that the differences in group means are statistically significant. All three ANOVA tests revealed significant differences between group means.

Discussion

The assessment of phytosociological parameters through quantitative data analysis is integral for understanding the variation in vegetation dynamics and patterns within forest ecosystems. In this context, the current study embarked on a comprehensive exploration of the diversity and floristic composition of vegetation across an altitudinal gradient within the fragmented forests of Kahuta (Table 2).

Dominant Species and Community Composition

The present study's findings highlight the dominant species in each zone, with *Pinus roxburghii, Olea ferruginea*, and *Acacia modesta* being prominent across multiple zones.
Dominant species significantly influence the vegetation structure across the respective zones. Shrubs such as *Dodonea viscosa, Carica opaca,* and *Agave sisalana* contribute to the ecosystem's diversity. While studying the vegetation variety throughout an altitudinal range in the Garhwal Himalaya, Rawat et al. (2015) discovered 79 woody species, including 29 trees and 50 shrubs. Only five tree species were recorded from altitudinal Zone I to Zone V (500-1750 meters above sea level) in the current study, which is somewhat higher than the study carried out *in a Betula utilis* forest by Shrestha et al. (2010) in a Trans-Himalayan dry valley in Central Nepal. Bhat et al. (2020) found 94 woody plant species, including 44 trees and 50 shrubs, while conducting a phytosociological investigation of woody vegetation in different altitudinal ranges of KWLS. This slight variance in species richness may be attributed to differences in local characteristics, such as temperature, altitude, humidity, and rainfall.

Importance Value Index

The IVI is crucial in evaluating the importance of species within plant communities. This is predicated on the assumption that there is a correlation between a species' assigned fraction of community resources and the community space utilised (Whittaker, 1965; Pandey et al., 2002). Three major species communities were identified. Species communities were studied at different elevations. Species in each community were classified based on their density, frequency percentage, cover and IVI. The study showed that *Pinus roxburghii, Acacia modesta, Olea ferruginea,* and *Dodonea viscosa* were also abundant, similarly *to Morus alba, Agave sisalana, Cassia fistula,* and *Carica opaca*. The findings of the current study align with those of Ghimire (2011). Ahmad et al. (2023) also examine density, abundance, and coverage during a vegetation valuation using the square method and worked to determine the IVI, which is similar to the present study.

Altitudinal Gradient Analysis

A one-way ANOVA performed throughout the altitudinal gradient demonstrates significant variations in density, frequency, and cover, indicating that altitude has a strong influence on vegetation patterns. The fact that the crucial F-values are exceeded indicates that the observed differences are statistically significant. The current study's findings are consistent with those of previous researchers, such as Sharma et al. (2009), who investigated broad-leaved mixed forests over an altitudinal gradient in the Garhwal Himalayas. The research was undertaken to investigate the influence of altitudinal variation on forest structure, with vegetation characteristics found to be highest at lower altitudes and lowest at higher altitudes.
Siddiqui et al. (2009) conducted a vegetation study in the Himalayan and Hindukush ranges of Pakistan during the summer at altitudes ranging from 750 to 1700 meters, which is similar to the findings of the current study, where quantitative attributes were calculated along the

elevation gradient. Furthermore, Hegazay et al. (1998) concluded that vegetation dynamics are mostly related to the increasing altitudinal gradient, with lower-altitude floral diversity being low, while it is maximum at middle altitudes but decreases beyond that, i.e., at higher altitudes, with very low floral communities. So this study is similar to the current study.

Community Dominance and Altitude

The primary species composition changed as one moved from lower to higher altitudes. While *Pinus roxburghii* remains dominant in Zone V, the relative importance of other species such as *Olea ferruginea* and *Acacia modesta* shifts downward. Temperature, moisture availability, and soil qualities that change with altitude may all influence this pattern.

The community dominance of richness of species reported in this research is well within the previously found values by Rana and Gairola (2010), in which the study was conducted in 3 altitudinal regions, namely the upper region, 550-850 m asl, the middle region, 500-700 meters asl, and the lower region, 350-450 meters asl, in which the middle zone was recorded with the highest tree species richness and the two zones have low community parameters, thus this further According to Sanjjay et al. (2008), height, size, and thickness decrease fast from low to high levels. Saplings and seedlings do not follow the patterns of the trees, but rather the patterns of the site area.

Conclusion

The extensive research conducted in the defined study region has provided valuable insights into the phytosociological characteristics and community dynamics of plant species across different zones and altitudes. Twelve species from 9 families were found, and their distribution and dominance within each zone were investigated. Findings highlight the importance of particular species in maintaining the ecological balance and diversity of the plant community. *Pinus roxburghii* is identified as a dominant species throughout all zones, suggesting its extensive distribution. This evergreen conifer repeatedly exhibited high IVI values, indicating its significant role in community structure and ecological interactions. Additionally, *Olea ferruginea*, a species also revealed great ecological relevance, notably in Zone III, where it had the highest IVI value.

The research also acknowledged the significant contributions of *Acacia modesta, Cassia fistula,* and *Morus alba* in certain zones, highlighting the dynamic nature of plant dominance in response to changing environmental conditions. Shrubs such as *Dodonea viscosa, Carica opaca,* and *Agave sisalana* served a complementary function in the ecosystem by enhancing the vegetation. A steady shift in species composition was observed as elevation increased from Zone I to Zone V, demonstrating how different species adapt to changing environmental gradients. *Pinus roxburghii's* dominance at higher elevations, notably in Zone V, demonstrates its extraordinary capacity to grow in challenging environments. *Pinus roxburghii* consistently emerges as a dominant species across multiple zones. With progressively decreasing IVI values from Zone I to Zone V (12.3, 20.1, 55.7, and 65.0, respectively), *Pinus roxburghii* influence remains pronounced, culminating in its exclusive dominance in Zone V.

Olea ferruginea, despite showing fluctuating IVI values (18.1, 16.7, 132.1, and 23.2), consistently displays substantial ecological importance, underscoring its key role in the plant community. This is particularly evident in Zone III, where *Olea ferruginea* emerges as the most influential species. Other species, such as *Acacia modesta, Cassia fistula, Morus alba, Dodonea viscosa, Carica opaca, Agave sisalana,* and *Jasminum* mesnyi, showcase varying degrees of importance across different zones, each with its distinctive characteristics. These findings parallel the conclusions drawn from the IVI values reported for each zone. As we delve into the specific IVI values, a consistent pattern emerges. In Zone I, the dominant species *Pinus roxburghii* boasts an IVI value of 12.3, while *Olea ferruginea* and *Acacia modesta* follow with

IVI values of 18.1 and 21.8, respectively. Zone II exhibits IVI values of 20.1 for *Pinus roxburghii*, 16.7 for *Olea ferruginea,* and 18.8 for *Acacia modesta*. Transitioning to Zone III, *Olea ferruginea* takes the lead with a remarkable IVI value of 132.1, closely trailed by *Pinus roxburghii* with an IVI value of 38.6. *Pinus roxburghii* continues its dominance in Zone IV with an IVI score of 55.7, followed by *Olea ferruginea* with an IVI value of 23.2. Finally, Zone V is dominated by *Pinus roxburghii*, which has an IVI rating of 65.0. ANOVA results align with the IVI values, indicating considerable variance in phytosociological features between zones and species.

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